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# IS THERE A COSMOLOGICAL CONSTANT?

NAG5-8831

FINAL REPORT

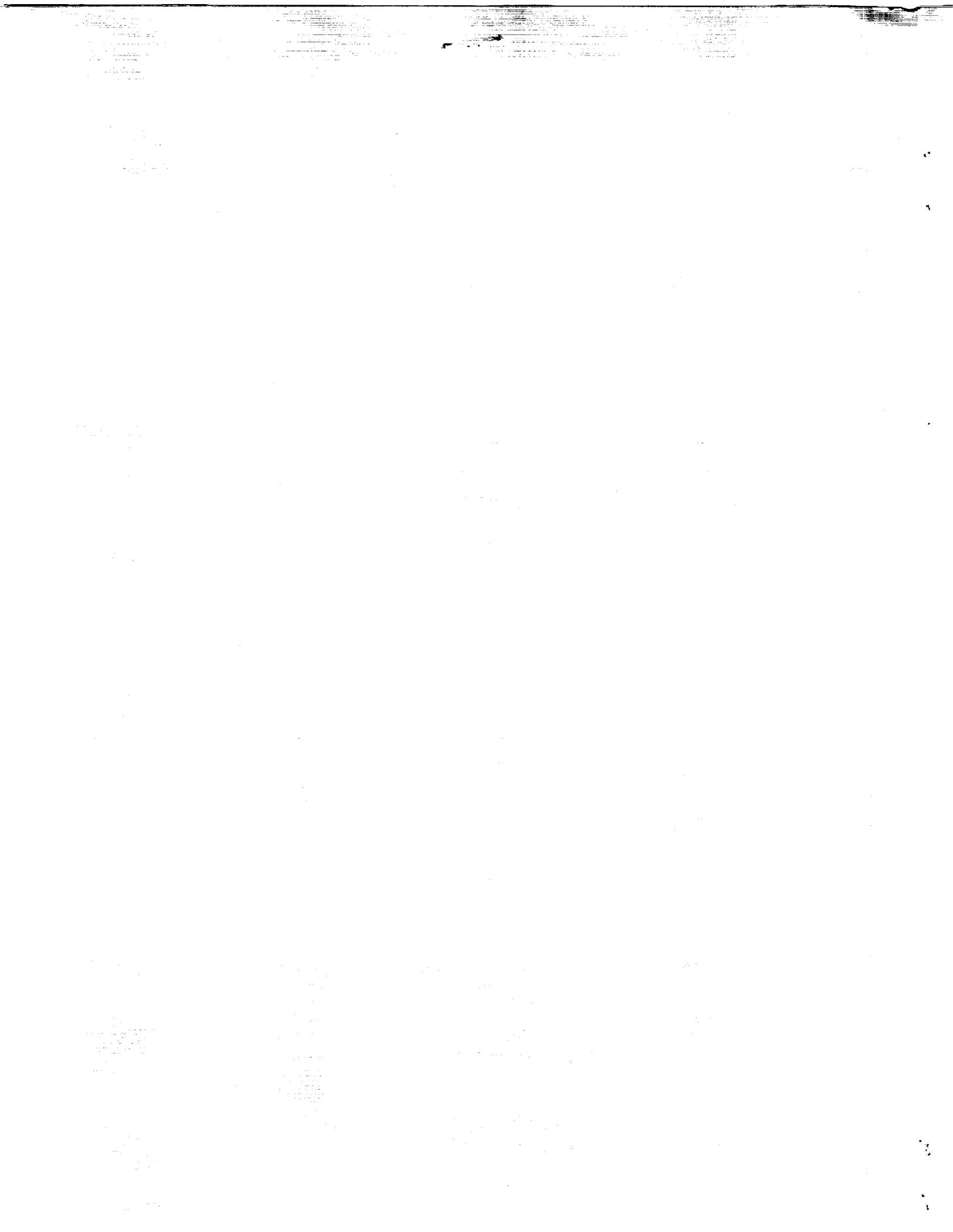
For the Period 1 July 1999 through 31 March 2002

Principal Investigator  
Christopher Kochanek

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Ronald J. Oliverson, Technical Officer  
NASA/GSFC  
Greenbelt, MD 20771-0001

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Final Report - NAG5-8831  
Is There A Cosmological Constant?

Dr. Christopher S. Kochanek  
Smithsonian Astrophysical Observatory

The grant contributed to the publication of 18 refereed papers and 5 conference proceedings. The primary uses of the funding have been for page charges, travel for invited talks related to the grant research, and the support of a graduate student, Charles Keeton. The refereed papers address four of the primary goals of the proposal:

- (1) the statistics of radio lenses as a probe of the cosmological model (#1),
- (2) the role of spiral galaxies as lenses (#3),
- (3) the effects of dust on statistics of lenses (#7, #8), and
- (4) the role of groups and clusters as lenses (#2, #6, #10, #13, #15, #16).

Four papers (#4, #5, #11, #12) address general issues of lens models, calibrations, and the relationship between lens galaxies and nearby galaxies. One considered cosmological effects in lensing X-ray sources (#9), and two addressed issues related to the overall power spectrum and theories of gravity (#17, #18). Our theoretical studies combined with the explosion in the number of lenses and the quality of the data obtained for them is greatly increasing our ability to characterize and understand the lens population. We can now firmly conclude both from our study of the statistics of radio lenses and our survey of extinctions in individual lenses that the statistics of optically selected quasars were significantly affected by extinction. However, the limits on the cosmological constant remain at  $\lambda_0 < 0.65$  at a  $2\sigma$  confidence level, which is in mild conflict with the results of the Type Ia supernova surveys. We continue to find that neither spiral galaxies nor groups and clusters contribute significantly to the production of gravitational lenses. The lack of group and cluster lenses is strong evidence for the role of baryonic cooling in increasing the efficiency of galaxies as lenses compared to groups and clusters of higher mass but lower central density. Unfortunately for the ultimate objective of the proposal, improved constraints on the cosmological constant, the next large survey for gravitational lenses did not release its results during the term of the proposal.

The research supported the career development of six graduate students (Dalal, Fletcher, Herold, Keeton, Peng and Rusin) and two post-docs (Lehar and Munoz).

Refereed Papers

- [1] *Limits on Cosmological Models From Radio-Selected Gravitational Lenses*, Falco, E.E., Kochanek, C.S., & Munoz, P., 1997, *ApJ*, *in press*
- [2] *MGC 2214+3550AB: A New Binary Quasar*, Munoz, J.A., Falco, E.E., Kochanek, C.S., Herold, L., Fletcher, A., & Burke, B.F., 1997, *ApJ*, **492**, 9.
- [3] *Gravitational Lensing by Spiral Galaxies*, Keeton, C.R., & Kochanek, C.S., 1998, *ApJ*, **495**, 157.
- [4] *The Optical Properties of Gravitational Lens Galaxies as a Probe of Galaxy Structure and Evolution*, Keeton, C.R., Kochanek, C.S., & Falco, E.E., 1998, *ApJ*, **509**, 561.

- [5] *An Infrared Einstein Ring in the Gravitational Lens PG1115+080*, Impey, C.D., Falco, E.E., Kochanek, C.S., Lehár, J., McLeod, B.A., Rix, H.-W., Keeton, C.R., Munoz, J.A. & Peng, C.Y., 1998, *ApJ*, **509**, 551.
- [6] *Why Quasar Pairs Quasar Binaries and Not Gravitational Lenses*, Kochanek, C.S., Falco, E.E. & Munoz, J.A., 1997, *ApJ*, *in press*
- [7] *The Infrared Einstein Ring in the Gravitational Lens MG1131+0456 and the Death of the Dusty Lens Hypothesis*, Kochanek, C.S., Falco, E.E., Impey, C.D., Lehár, J., McLeod, B.A., Rix, H.-W., Keeton, C.R., Munoz, J.A. & Peng, C.Y., 1999, *ApJ*, *submitted*
- [8] *Dust and Extinction Curves in Galaxies with  $z > 0$ : The Interstellar Medium of Gravitational Lens Galaxies*, Falco, E.E., Impey, C.D., Kochanek, C.S., Lehár, J., McLeod, B.A., Rix, H.-W., Keeton, C.R., Munoz, J.A. & Peng, C.Y., 1999, *ApJ*, *submitted*
- [9] *Finding Gravitational Lenses With X-rays*, Munoz, J.A., Kochanek, C.S., & Falco, E.E., 1999, *ApJ*, **521**, 17.
- [10] *The Quasar Pair Q 1634+267 A, B and the Binary QSO vs. Dark Lens Hypotheses*, C.Y. Peng, Impey, C.D., Falco, E.E., Kochanek, C.S., Lehar, J., McLeod, B.A., Rix, H.-W., Keeton, C.R., & Munoz, J.A., 1999, *ApJ*, **524**, 572.
- [11] *HST Observations of 10 Two-Image Gravitational Lenses*, Lehar, J., Falco, E.E., Kochanek, C.S., McLeod, B.A., Munoz, J.A., Impey, C.D., Keeton, C.R., Peng, C.Y., & Rix, H.-W., 2000, *ApJ*, **536**, 584.
- [12] *The Fundamental Plane of Gravitational Lenses and the Evolution of Early-Type Galaxies In Low Density Environments*, Kochanek, C.S., Falco, E.E., Impey, C.D., Lehar, J., McLeod, B.A., Rix, H.-W., Keeton, C.R., Munoz, J.A., & Peng, C.Y., 2000, *ApJ*, **543**, 131.
- [13] *Multi-Frequency Analysis of the New Wide-Separation Gravitational Lens Candidate RX J0921+4529*, Munoz, J.A., Falco, E.E., Kochanek, C.S., Lehar, J., McLeod, B.A., McNamara, B.R., Vikhlinin, A.A., Impey, C.D., Rix, H.-W., Keeton, C.R., Peng, C.Y., & Mullis, C.R., 2001, *ApJ*, **546**, 769.
- [14] *The Importance of Einstein Rings*, Kochanek, C.S., Keeton, C.R., & McLeod, B.A., 2001, *ApJ*, **547**, 50.
- [15] *B1359+154: A Six Image Lens Produced by a  $z = 1$  Compact Group of Galaxies*, Rusin, D., Kochanek, Norbury, M., Falco, E.E., Impey, C.D., Lehar, J., McLeod, B.A., Rix, H.-W., Keeton, C.R., Munoz, J.A., & Peng, C.Y., 2001, *ApJ*, **557**, 594.
- [16] *Global Probes of the Impact of Baryons on Dark Matter Halos*, Kochanek, C.S., & White, M., 2001, *ApJ*, **559**, 531.
- [17] *Constraints on the long-range properties of gravity from weak gravitational lensing*, White, M., & Kochanek, C.S., 2001, *ApJ*, **560**, 539.
- [18] *Strong Lensing Constraints on Small-Scale Linear Power*, Dalal, N., & Kochanek,

C.S., 2002, *PRL*, *in press*

Conference Proceedings

- [1] *Gravitational Lenses & NGST*, Kochanek, C.S. 1997 in the Science With NGST.
- [2] *Results From the CASTLES Survey of Gravitational Lenses*, Kochanek, C.S., Falco, E.E., Impey, C.D., Lehár, J., McLeod, B.A., & Rix, H.-W., 1998 in *After the Dark Ages: When Galaxies Were Young*.
- [3] *Mass Follows Light*, Kochanek, C.S., 2001, proceedings of the Yale Cosmology Workshop on the Shapes of Galaxies and Their Halos
- [4] *Dynamical Probes of the Halo Mass Function*, Kochanek, C.S., 2001, *The Dark Universe*, ed., M. Livio, (Cambridge University Press: Cambridge)
- [5] *Detection of CDM Substructure*, Kochanek, C.S., & Dalal, N., 2001, *The Mass of Galaxies at Low and High Redshift*, ed., R. Bender

